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Effect of mistletoe on the growth of western yellow pine. Long + Korstian

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INTRODUCTION

During the past eight years, studies have been in progress the object of which was to determine the effect of the yellow pine mistletoe (Razoumofskya cryptopoda (Engelm.) Cov.) on the growth and seed production of western yellow pine (Pinus ponderosa). Western yellow pine is by far the most important timber tree of the Southwest, comprising over 80 per cent of the commercial forests of Arizona and New Mexico or approximately 17 billion board feet.

The yellow pine mistletoe is very widely distributed in the western yellow pine forests of the Southwest and occurs in

such abundance in many localities as to assume a very serious aspect in relation to many forest problems. In fact, the mistletoe is the most widely distributed and one of the most serious diseases of the western yellow pine. The mistletoe pest has confronted the forester from the beginning of silvicultural practice in the Southwest. In marking western yellow pine for cutting, the question is often raised as to the advisability of cutting trees of various ages and degrees of mistletoe infection or of allowing them to stand as seed trees and form a part of the future stand which will provide the basis for a subsequent cut. The solution of this problem involves not only a study of the effect of mistletoe on the rate of growth and the longevity of its host, but also the effect of the parasitism on the amount and periodicity of seed production.

PHYSICAL AND CLIMATIC FEATURES OF THE REGION

The localities in which the intensive studies were conducted, lie within the Coconino and Tusayan National Forests

on the Colorado Plateau, near the San Francisco Mountains in northern Arizona. The general topography of the Plateau is rolling and consists of alternating flats comparatively free from rock and of rather low ridges which are very rocky. The underlying rock of the Plateau consists principally of Coconino sandstone and Kaibab limestone overlain by a lava flow of basalt and acidic volcanic rocks, mainly dacite, andesite, rhyolite and latite, which comprise the main outcrops and surface rocks of the region. The soil varies widely from a fine sandy loam to a reddish friable clay, often containing an admixture of gravel and large volcanic boulders. In a greater part of the region northeast of the San Francisco Mountains the soil is covered with black volcanic cinders to depths varying from 1/2 to about 18 inches. Mistletoe infection is rare on these cinder areas and where found at all is light. The level mesas and lower slopes of the Plateau ranging from approximately 6,500 to 8,500 feet in elevation are covered with a forest of which approximately

95 per cent is western yellow pine, comprising the most extensive forest of this species in North America.

The climate of that portion of the Colorado Plateau which is covered with a western yellow pine forest may be exemplified by the climatological data which has been secured at the Ft. Valley Experiment Station during the period from 1909 to 1916, inclusive, as summarized in Table 1. Pearson[1] has previously shown that the climate of this region is characterized

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[1] Pearson, G. A. A meteorological study of parks and timbered areas in the western yellow pine forests of Arizona and New Mexico. Monthly Weather Review 41; 1615-1629, 1914.

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by marked seasonal variations in precipitation, atmospheric humidity, and wind movement and great daily ranges of atmospheric temperature. The amount of sunshine is unusually high. The mean annual precipitation in the western yellow pine forest amounts to between 20 and 25 inches which occurs in two well-defined periods, during July and August in the form of thunder showers, and from November to April in the form of snow. The intervening period from about April 15

to July 15, is characterized by high dessicating southwest winds and excessive evaporation which, together with the small amount of precipitation, produce conditions adverse to most types of vegetation. The high rate of evaporation very often causes excessive transpiration from the plant. The climatic and soil conditions are such that nowhere within the western yellow pine type of the Southwest does this species make rapid growth.

The influence of such climatological conditions is generally considered unfavorable to the best development of the host and favorable to the growth of the parasitic mistletoe. Weir[2] has shown that the ecological relationships of the mistletoes

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[2] Weir, James R. The larch mistletoe: Some economic considerations of its injurious effects. U. S. Dept. of Agri. Bul. 317, pp. 5-10, 1916.

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although they are parasitic, are similar to those of other chlorophyllaceous plants in that they also respond to light, gravity and chemical stimuli, while the marked variations in temperature to which the host readily responds are only slightly effective

on the parasite. The low atmospheric humidity has a very slight influence on the xerophytic mistletoe while the great amount of sunshine is favorable to the light-loving tendencies of the parasite. The unusually high winds of the Southwest frequently cause rather serious losses to western yellow pine stands in exposed situations through windfall, while the wind is known to actually aid in the dissemination of the mistletoe seed from tree to tree. It is thus evident that the climate must exert a favorable influence toward the pathogenicity of the parasitic mistletoe in the Southwest. It follows then that, where a virulent parasite with decided pathogenic tendencies responds favorably to its habitat, the host will rapidly deteriorate on the more unfavorable sites. From numerous observations made by the writers in various parts of the Southwest it is apparent that a rather definite relation exists between the unfavorableness of the site and the severity of mistletoe infection. The percentage of infection and the resulting mortality of the host is usually higher on ex-

posed dry ridges and south slopes than on the more favorable sites. This condition is very apparent on the Santa Fe National Forest in northern New Mexico.

THE YELLOW PINE MISTLETOE

The family Loranthaceae has two genera in the United States, Phoradendron and Razoumofskya. The species of Phoradendron are parasitic on both hardwoods and conifers, but mainly on hardwoods, while the genus Razoumofskya is found exclusively on conifers. Several species of the latter genus are rather common in the Western United States and in some localities have become very serious parasites. Razoumofskya cryptopoda, the yellow pine mistletoe, is probably one of the most widely distributed of all the species, being found wherever the western yellow pine grows.

Razoumofskya cryptopoda (Engelm.) Coville:

Plants evergreen, parasitic, dichotomously branched, with swollen joints and opposite thick, coriaceous exstipulate, entire leaves reduced to mostly connate scales; stems about 4-12

cm. high, 3-6 mm. thick at base, much branched, paniculate, brownish-yellow to dark olive-brown, staminate plants smaller than pistillate ones; flowers small, inconspicuous, greenish, dioecious, mostly three parted 3-4 mm. broad, staminate flowers in the axes of the scales of a simple or compound spike, spikes short, stout, 3-4 mm. in diameter; anthers as many as the sepals and episepalous, attached above the middle of the ovate, acute lobes; ovary inferior, one-celled, fruit a berry with a gelatinous endocarp, 4-5 mm.long. When ripe the seeds are suddenly and forcibly ejected to a distance of several yards.

Razoumofskya cryptopoda flowers in Arizona and New Mexico during April and May, and the fruit matures in August and September of the next year. When the seeds begin to ripen, the berries gradually turn downward on their pedicels until the base of each berry when fully mature, points upward into the air. The seeds are discharged by a ring of tissue situated near the base of the berry suddenly giving way and the gelatinous seed is forcibly ejected

upward into the air from the rear of the berry. This method of seed dissemination is common to all of the species of Razoumofskya. The limited experiments conducted by the writers, as well as extended observations, indicate that both staminate and pistillate plants die and fall from the trees after one season of flowering and fruiting.

EFFECT OF MISTLETOE ON GROWTH OF HOST

The study of the effect of mistletoe on its host was accomplished, (1) by periodic measurements and observations on standing trees, both infected and healthy; and (2) by detailed growth studies and observations of infected and healthy felled trees.

Effect on Bole of Tree

Ninety-one healthy and mistletoe-infected trees on three different areas within a radius of five miles of the Fort Valley Experiment Station were tagged, numbered, measured and mapped in 1910 with the object of determining the effect of

mistletoe on the diameter and height growth of the host, the diameter growth of limbs, and the merchantable growth, i.e., the growth of the merchantable contents of the bole. The diameters were carefully measured with a diameter tape at 1, 4.5, 17 and 33 feet above the ground. The total heights were measured with a Forest Service standard hypsometer. The diameters of 54 limbs on 18 standing trees were measured with a view of determining the effect of mistletoe on the growth of limbs of western yellow pine trees. The points of measurement were marked by driving a 6d copper nail into the wood. All of the trees were remeasured in 1915, and were classified into four degrees of mistletoe infection, according to the prevalence of mistletoe on the tree as follows: o = healthy trees without mistletoe, x = light mistletoe infection, xx = medium mistletoe infection, xxx = heavy mistletoe infection.

In order to check any material effect that the different crown classes might have on the rate of growth, the trees

were also classified, according to their dominance or relative position in the crown cover, into the following crown classes:

Isolated: Trees growing in the open which do not form a contiguous part of the regular forest canopy.

Dominant: Trees with crowns extending above the general level of the forest canopy and receiving full light from above and partly from the side; larger than the average trees in the stand, and with crowns well developed, but possibly somewhat crowded.

Codominant: Trees with crowns forming the general level of the forest canopy and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides.

Intermediate: Trees with crowns below, but still extending into the general level of the forest canopy, receiving a little direct light from above but none from the sides, usually with small crowns considerably crowded on the sides.

Suppressed: Trees with crowns below the general level of the forest canopy and receiving no direct light either from above or from the sides; usually with small, poorly developed crowns.

It would have been impracticable, however, to segregate by crown classes, all of the trees used in this study because of the relatively small number which would have fallen into each age-infection-crown class, had such a triple classification been used.

There are two well-recognized forms of Pinus ponderosa, "black Jack" and "yellow pine", based on age, rate of growth, and the resulting color of the bark. The term "black jack" applies to the young vigorous trees under 125 to 150 years old, which are characterized by a dark, almost black, or dark brown, narrow-furrowed bark. The "yellow pine" form comprises the older trees which are characterized by a yellowish or reddish brown, widely furrowed bark. There is a marked difference in the form and volume of black jacks and yellow pines. The average black jack has a greater taper, a more rapid rate of growth, and approximately 10 per cent smaller cubic volume than the average yellow pine of the same diameter and height which were the chief reasons for the segregation of black jack and yellow pine in Tables 2 to 13 inclusive.

The mean diameter growth or accretion of the standing black jacks for the 5-year period from 1910 to 1915 grouped according to degree of mistletoe infection is shown in Table 2.

The diameters were averaged by infection classes for each year, and the difference was computed as the growth during the 5-year period or the periodic accretion. The average growth per year during the period considered is termed the periodic annual accretion. The data show an almost consistent decrease in the rate of diameter growth of black jack varying with the degree of mistletoe infection. The slight inconsistency exhibited in the rate of diameter growth of the o and x infection classes can be explained by the fact that of the 27 trees in the former class, 11 per cent were isolated trees which did not form a part of the forest canopy, 28 per cent were dominant, 57 per cent were co-dominant and 4 per cent were intermediate trees, while with the latter infection class 60 per cent were isolated trees which did not form a part of the forest canopy and 40 per cent of the trees were in the codominant crown class. Table 3 consistently shows a decrease in the rate of diameter growth of yellow pine which varies directly with the degree of mistletoe infection.

Table 4 shows the total volume growth or increment of

the standing black jacks for the 5-year period, grouped by infection classes. The total volumes were computed by applying a volume table based on diameter and total height to the dimensions of each tree at each time of measurement. The volumes of all trees were totaled by infection classes. The difference between the total volumes at each time of measurement represents the periodic increment and the average volume growth per year during the period considered is the periodic annual increment. Table 5 shows the increment of the standing yellow pines for the same 5-year period. Both forms of western yellow pine exhibit a consistent decrease in the increment of those trees which are infected with mistletoe varying directly with the degree of infection.

Bole measurements were made at 16-foot intervals to insure greater accuracy in the study of the effect of mistletoe on the growth of the merchantable contents of the bole of the tree. Table 6 gives a comparison of the diameter growth of the bole of 33 trees at 4.5, 17 and 33 feet above ground. The comparative

increments of the same trees is shown in Table 7. The apparent discrepancy between the rate of growth of the uninfected and lightly infected classes, as was noted above, is apparently due to the varying proportions of the trees among the different crown classes. In computing the volumes, each section below the highest point of measurement was cubed as a cylinder and that portion above was considered as the top of the tree and its volume was computed as that of a cone.

The growth of the standing trees was further checked by complete stem analyses of 102 felled trees. Sections were examined as near as possible to the surface of the ground, at 4.5 feet above the ground, and at every eight feet above this point. The measurements were recorded by 5-year periods instead of by decades as is the usual practice in complete stem analysis. The trees were selected as near as possible from the same site, kind of stand, and the same age and crown classes. Only those trees free from abnormalities or other possible causes of de-

terioration or conditions deterrent to their growth were studied, thus permitting only two variables to enter into the results, namely, the age of the tree and the degree of mistletoe infection.

The basic data for each of the individual felled trees which were analyzed to show the effect of mistletoe on the growth and seed production of western yellow pine have been arranged in Table 8, according to the age of the trees. In compiling the stem analyses the data for each individual tree were computed separately. The diameters and heights of each tree for each fifth year, dating back from the year of analysis, were correlated with age in growth analysis diagrams, from which the dimensions of each tree for each integral five years of age or quinquennium were read.

Figure 1, shows the graphical growth analysis diagram for Tree No. 47, a typical healthy western yellow pine, while Figure 2 shows the same kind of a diagram for Tree No. 42, which was heavily infected with mistletoe. Since the tree is only 94

years old its age cannot be held accountable for the falling off in the increment. Both trees grew within a short distance of each other on the same site. If the difference in the crown class of the two trees had an appreciable effect on the rate of growth Tree No. 42 should show the more rapid growth since it is an isolated tree which does not form a part of the forest canopy while Tree No. 47 belongs to the codominant crown class. The very marked decrease in the rate of growth during the last 20 years due to the parasitism of the mistletoe is very clearly shown by the closeness of the last five quinquennial lines near t the outside of the cone in Figure 2, which represents the growth of Tree No. 42.

A complete set of curves was drawn for each tree relating diameter breast high, total height and volume to age. This curving eliminated the irregularities and irrelevant abnormalities occurring in each tree. The data for the individual trees were then averaged by a series of harmonized

curves for each infection and 40-year age class. Forty-year age classes were used instead of the usual 20-year age classes because this provided a greater number of trees as the basis for each age and infection class.

The harmonized volume-age curves for the 21 to 60 and the 61 to 100 year age classes are shown in Figure 3, which indicates that the mistletoe infection was sufficiently severe to retard the rate of growth of the more heavily-infected trees of these two age classes for approximately 25 to 30 years. Figure 4 shows the same retardation of the increment for the 101 to 140, and the 201 to 240 year age classes except that the rate of growth of the more heavily infected trees of these age classes has been falling off for the past 70 to 80 years. The curves in both figures show conclusively that the current increment is directly dependent upon the degree of mistletoe infection. Generally speaking the degree of mistletoe infection increases with the length of time which a tree has been infected.

A further comparison of the average diameter growth or accretion of the felled western yellow pine trees for the 25-year period from 1890-1915, grouped by 40-year age classes and degree of mistletoe infection, is shown in Table 9. A similar comparison of the average height growth or accretion of the same trees is given in Table 10. Table 11 shows a comparison of the average volume growth or increment of the same trees for the same period, similarly grouped by age and infection classes. The 21 to 60, 61 to 100, and the 101 to 140-year age classes in Tables 9, 10 and 11, are composed entirely of black jacks while yellow pines constitute the 201 to 240-year age class.

Two seedlings, one healthy and the other heavily-infected with mistletoe, which were growing side by side on a good site, were analyzed and both found to be 15 years old. The healthy seedling showed marked vigor and was four feet tall, whereas the one infected with mistletoe was only three feet tall and showed evident stunting and that death was imminent.

The data presented in the preceding pages prove conclusively that although minor fluctuations are exhibited, the rate of growth of the host decreases directly with the amount of mistletoe infection or in other words, is dependent on the degree of parasitism. These results are really to be expected when the nature of mistletoe parasitism is fully understood.

Effect on Limbs:

The first visible effect of the infection of a limb by mistletoe is the formation of a fusiform swelling about the center of infection. This hypertrophy is the first stage of a later abnormal growth of branches from the enlarged portion, which results in the formation of witches' brooms. When the stimulus of the parasite has once become manifest through the formation of a broom the tendency toward abnormal branching continues although the mistletoe may have died.

The comparative diameter growth or accretion of 54 limbs on 18 standing black jacks is averaged by infection

classes in Table 12. Measurements were taken at six inches from the bole of the tree and every six inches beyond this point. The measurements taken at 6 and 18 inches from the bole of the tree were averaged and are presented in the table to facilitate a clearer and more comprehensive interpretation of the significant data. Sufficient limb measurements were also taken on the felled trees to check the comparative growth of the healthy and mistletoe-infected limbs of the standing trees. From these data which are summarized in Table 13, it is apparent that the limbs had been infected at least 25 years prior to the time at which they were analyzed. The data presented in both tables conclusively show that limbs infected with mistletoe exhibit an increased diameter growth up to a certain point beyond which there is a decrease in the rate of growth until the limb ultimately dies. This increased diameter growth is probably caused by the formation of an excessive amount of parenchyma tissue as a result of the irritation of the cambium by the parasite. The softer parenchyma tissue adjacent to the center

of infection renders the infected wood somewhat weaker than the more highly-lignified tissues of normal uninfected wood. The presence of the mistletoe in the limb produces a stimulated growth of the host at the point of infection by causing the host to exert an effort to overcome the effect of the parasitism of the mistletoe.

Eccentricities are considerably more pronounced in limbs heavily infected with mistletoe than in healthy limbs. The formation of a large witches' broom produces an abnormally heavy load which must be borne by that portion of the limb nearest to the bole of the tree. This abnormal load is believed to produce stresses which are sufficient to stimulate the formation of wood on the under side of the limbs through the deposition of food materials and in this way rendering it more able to withstand the compression below and the tension above.

The larger size of the limbs infected with mistletoe renders limbing and brush disposal in logging operations more difficult and consequently more expensive. The excessive

secretion of resin which occurs in mistletoe-infected limbs also renders brush disposal somewhat more difficult and expensive.

Hypertrophy and Resin Flow:

As previously stated, there is more or less hypertrophy at the point of mistletoe infection. This hypertrophy is usually accompanied by a copious flow of resin, which appears as small drops usually on the lower side of limbs which are heavily infected with mistletoe. A cross section through such a limb shows large areas of the sapwood thoroughly infiltrated with resin. This process of infiltration continues on many of the limbs until the fibro-vascular system is thoroughly clogged with resin and the limb girdled as far as receiving any food supply is concerned and finally dies. This process is usually very gradual but nevertheless sure.

The resin flow from such mistletoe-infected limbs is not caused by insect punctures since a careful examination of the resin infiltrated areas fails to show any sign of insect

injury. On many of the heavily infected mistletoe trees, resin cankers of varying sizes are found on the bole. These cankers are often directly associated with local mistletoe infection, but some occur where no such infection is evident. Whether these bole cankers are due entirely to mistletoe infestation is an open question which further investigation will have to determine. These resin flows on the bole are always indicative of a tree on the decline; in fact, trees with marked resin flow cankers usually die in six to ten years' time. Such trees therefore should never be left for seed or protection purposes.

Effect on the Foliage

Tables 14, 15 and 16, show the effects of the mistletoe on the foliage of the western yellow pine. The data included in Table 16 were obtained as follows:

Each tree crown was divided into three divisions, bottom middle and top, including in each division about one-third of the total leaf surface. One hundred tufts from each section were selected at random and measured. The mean length of these 100

tufts was taken as the average length per tuft for that section; then 10 tufts of this average length were taken from each of the three sections into which the crown had been divided. These 10 tufts, 30 in all for each tree, were cut off and taken to the laboratory where the number of leaves per tuft, the length and width of each leaf were determined. The total number of tufts in bottom, middle and top thirds was determined by actual count. The number of tufts thus obtained were multiplied by the average number of leaves found in the 10 tufts from each section. This gave the total number of leaves in each section. The sum of the leaves in the three sections gave the total number of leaves in any given tree crown. The average length and width of the leaves in the 10 tufts selected were used as one of the factors in determining the leaf surface for a given section of the crown and these in turn for finding the total leaf surface of a given tree. Table 16 shows that not only does the mistletoe shorten the length of both leaf tufts and leaves, but it also materially

decreases the number of leaf tufts per tree for heavily infected trees when compared with healthy trees of the same age and site conditions. When two trees, one healthy and the other heavily mistletoed, of the same size are compared, like Trees 103 and 107, it is seen that it has taken the mistletoe-infected tree more than twice the number of years to reach the same size as the healthy tree.

Trees heavily infected with mistletoe have considerably shorter leaves and leaf tufts than healthy trees. The leaves of mistletoe-infected trees are lighter in color than those of healthy trees, being a yellowish green on the infected trees and an olive green on the healthy trees. Each heavy infection causes a localization and reduction of the photosynthetic or assimilatory leaf surface of the tree which, in turn, results in the marked decrease of the increment.

Effect on Longevity of Host

A number of permanent sample plots were established on the Coconino and Tusayan National Forests by the Fort Valley

Experiment Station in 1909 to determine the rate of growth and decadence, the rate of establishment of natural reproduction, and the effect of various factors upon regeneration on cut over areas. These plots were remeasured in 1914 and some of them yielded valuable data on the amount of mistletoe infection and the resulting mortality on cut-over areas.

On an area of 456 acres on the Tusayan National Forest about five miles from the Fort Valley Experiment Station, 2,636 black jacks or 34.9 per cent of the total number of black jacks and 225 yellow pines or 34.8 per cent of the total number of yellow pines on the plot were infected with mistletoe. In many instances the infection was not sufficient to render the tree unhealthy but it is only a matter of time until practically all of the infected trees will pass through the various infection classes and ultimately die.

All of the trees which had died on the plots during the 5-year period were carefully examined and the cause of death noted. On the plot of 456 acres on the Tusayan National Forest

170 black jacks died during the 5-year period, or 2.2 per cent of the total number of black jacks living on the plot in 1909, while 21 yellow pines died during the 5 years which is 3.4 per cent of the total number of yellow pines living on the area. On a plot of 135 acres located on the Coconino National Forest about 1-1/2 miles from the Fort Valley Experiment Station, 27 black jacks died during the five years which is 1.1 per cent of the total number of black jacks living on the plot in 1909 while 26 yellow pines died during the 5-year period or 1.8 per cent of the total number of yellow pines living on the area.

A digest of that part of the detailed records pertaining to mistletoe as a cause of death of western yellow pine is given in Table 17.

The 456-acre plot on the Tusayan National Forest is located on an area which has sustained heavy losses from mistletoe while the 135-acre plot on the Coconino is located on an area with only occasional heavy infections. A study of Table 17 indicates that of the 170 black jacks on the former plot which

died during the 5-year period, 26.4 per cent were killed directly by the mistletoe combined with other agencies and only 31.3 per cent of the total number of black jacks died from other causes, while only 4.8 per cent of the yellow pines were killed by mistletoe combined with bark beetles. On the 135-acre Coconino plot mistletoe infection resulted in the death of 7.5 per cent of the total number of dead black jacks and 7.9 per cent of the total number of dead yellow pines, while mistletoe was a contributing factor toward the death of an additional 20.2 per cent of the yellow pines. During the five years 1.5 per cent of the total number of black jacks on the Tusayan plot in 1909 were killed by mistletoe alone or in conjunction with other agents, mainly insects.

From the data presented above it is evident that the number of trees which die as a result of combined attacks of mistletoe and insects is considerable. Weir[3] has noted the same

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[3] Weir, James R. Mistletoe Injury to Conifers in the Northwest. U. S. Dept. Agri. Bulletin 360, 39 pp., 1916

direct relation between mistletoe infection and insect infestation in the Northwest, especially with Dendroctonus valens. The origin of numerous insect infestations has been traced to stands of western yellow pine heavily infected with mistletoe. The main difference between mistletoe and insect injury is in the length of time required for the injury to become manifest. A sporadic insect infestation may develop rapidly and may kill a large number of trees in a relatively short time and it may even continue to increase until it is overcome and reduced to normal proportions through some natural agency. On the other hand the mistletoe develops comparatively slowly but continually and persistently. The bark beetles, when attracted by the resinous exudations of the mistletoe-infected trees, may materially hasten the death of the host which has been already weakened by the parasitic mistletoe. Trees dead or dying from mistletoe infection have been found infested with species of secondary bark beetles and borers, such as Ips, Pityophthorus, Chrysobothris, and Melanophila.

Three black jack saplings under four inches in diameter breast high on one of the intensive mistletoe study plots died during the 5-year period as a direct result of mistletoe infection. Five yellow pines on the same area were also killed by mistletoe during the same period. Many of the other trees on the sample plots, although not dead at the last examination, were small and stunted. They were making an almost inappreciable growth and were very unhealthy in appearance. Some of these, which are apparently unable to endure the parasitism of the mistletoe combined with a rather adverse climate, will undoubtedly succumb before the next remeasurement of the plots at the end of the second period of five years. Practically all of the trees which are heavily infected with mistletoe are ultimately doomed since it is only a question of the length of time which they can withstand the devitalizing effects of the parasite.

EFFECT OF MISTLETOE ON MERCHANTABILITY OF TIMBER:

Although the mistletoe injury to the host results less in the depreciation of the lumber than in the impairment of the

vital physiological functions of the host, there is nevertheless an appreciable effect on the quality of the lumber. The accelerated growth of mistletoe-infected limbs, as shown in Tables 12 and 13, results in larger limbs which produce knots of a larger size in the lumber that is sawed from mistletoe-infected trees. The increased size of the knots may, in many cases, be sufficient to materially lower the grade of the lumber. Mistletoe infection tends to produce a curly or abnormally grained wood. The wood is very frequently discolored and pitchy which is due in most cases to the resinous flow or bleeding of the tree as a result of the parasitism. A seedling or sapling whose stem is infected with mistletoe will seldom develop a bole large enough to yield any quantity of lumber and very rarely, if at all, lumber of a high grade. It is therefore evident that, aside from the physiologically injurious effect of the mistletoe, it also introduces a cull factor in that mistletoe-infected trees often produce a poorer grade of lumber than healthy trees.

EFFECT OF MISTLETOE ON SEED PRODUCTION OF HOST

Pearson[4] has shown, as a result of seed collected in

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[4]Pearson, G.A. The influence of age and condition of the tree upon seed production in western yellow pine. U.S. Dept. of Agri. Forest Service Cir. 196, 11 pp. 1912.

1909, that seed from mistletoe-infected black jacks gave a germination of 17 per cent below that of healthy black jacks, which had a final germination of 78 per cent. This study led to the conclusion that, although the mistletoe stimulates growth in that portion of the host adjacent to the parasite, causing the abnormal development of certain limbs and branches into witches' brooms, the excess of carbohydrates produced by the additional foliage of the mistletoe-stimulated branches is consumed by the parasite. The final result upon the trees in all cases is devitalizing.

In order to further check this theory additional seed collections were made by the Fort Valley Experiment Station in 1913 and 1915, from mistletoe-infected trees and healthy western yellow pines. The cones from each tree were kept separate and the seed extractions and germination tests were conducted separately

for the seed of each tree. Five hundred seeds from each lot were germinated in sand in the greenhouse at a temperature ranging from 40 to 90 degrees F., with a mean daily temperature of approximately 65 degrees. Daily counts were made during the progress of the germination tests, which continued for approximately 50 days. The pertinent data on the seed production of 64 felled western yellow pine trees for the 1913 and 1915 collections is classified in Table 18 according to the degree of mistletoe infection. The best criterion by which to judge the relative seed production is believed to be the reproductive value of each tree or the total number of viable seeds produced per tree which represents a convenient summation of the fundamental variables of seed production. This is obtained by multiplying the yield per tree in pounds of clean seed by the number of clean seeds per pound, and in turn multiplying the product by the final germination per cent. It will be noted that, with the exception of the lightly-infected class upon which the mistletoe has very little

if any effect, there is a decrease in the final germination per cent the yield of cones, and clean seed per tree and consequently a marked decrease in the reproductive value per tree with an increase in the amount of mistletoe infection. The reproductive value of the trees in the intermediate infection class is about 40 per cent of that of the healthy class, while the reproductive value of the trees in the heavily-infected class falls to only about 25 per cent of that of the healthy class. This is really not at all surprising when the nature of the parasitism is fully understood. The data for the mistletoe-infected classes of felled trees reported in Table 18 is meagre because of the difficulty experienced in securing seed from mistletoe-infected trees, owing to the sterility of the cones and their failure to develop. In fact, a diligent search was made for heavily-mistletoed trees which were bearing seed.

The extent and condition of the seed crop on the standing trees on the permanent sample plots referred to above, was under observation from 1912 to 1916 in order to secure additional data

on the effect of mistletoe infection on the amount and periodicity of seed production. The 1912 seed crop was rather light, only a few of the trees bore any large quantity of cones. In 1913 there was an average crop, with practically none in 1914, while the 1915 seed crop was rather light. The records of the 1912 and 1915 seed crops for 177 of the living western yellow pines are classified in Table 19 by degree of mistletoe infection and amount of the seed crop. The seed crops were arbitrarily classified by the same observer as heavy, good, medium, light or none. An analysis of the data shows that the amount of seed production varies inversely with the degree of mistletoe infection; as the degree of mistletoe infection increases the amount of seed produced decreases until very little, if any, seed is produced by heavily infected trees. Trees heavily infected with mistletoe produce small amounts of seed at such times as there are generally heavy seed crops, and at other times practically none. The few cones that may occasionally be found on trees heavily infected

with mistletoe are very often aborted, and are frequently infested with a cone insect (Conophthorus ponderosae)[5].

[5]Material determined by Office of Forest Insect Investigations, Bureau of Entomology, U. S. Dept. of Agriculture.

The same deterrent effect of mistletoe on the seed production of its host has also been found to obtain in the Northwest.[6]

[6]Weir, James R. Mistletoe Injury to Conifers in the Northwest. U. S. Dept. of Agri. Bull. 360, 39 pp., 1916.

It seems very improbable that mistletoe would ever act as a stimulus upon seed production, because its slow insidious action makes constantly greater demands upon the vitality of its host. Trees moderately or heavily infected with mistletoe are of little or no value for the purpose of seed production.

Foresters recognize the fundamental fact in silviculture as established by European studies,[7] that variations in the individual characteristics of the parent trees are hereditarily

[7]Engler, Arnold. Einfluss der Provenienz des Samens auf die Eigenschaftern der forstlichen Holzewache. Mitteilungen der Schweizerchen Contralanstalt fur das forstliche Versuchswesen, Zurich, 1905, B. 8, s. 81-236; 1913, B. 10, s. 1-386.

transmitted through the seed. The extent to which the origin of the seed influences such transmitted characteristics as the resistance or immunity to disease, the rate of growth, and the growth-form of the regenerated forest is of vital importance in the rational practice of scientific forestry.

Zederbauer[8] has shown that trees grown from seed collected from intermediate, suppressed and weakened trees are

[8]Zederbauer, E. Centralblatt fur das gesamte Forstwesen, 1912, s. 201.

less resistant to disease than trees grown from seed produced by dominant and vigorous trees. The hereditary characters of the species are not changed materially during one rotation. Several generations are necessary to show the true effects of those characteristics of the mother tree which may be transmitted through the seed, such as any unusual divergence from the typical

silvical characteristics of the species. A clearer conception of the latent possibilities of disease resistance and immunity of a species obtained through tree breeding is of vast importance in the silvicultural improvement and management of the forest. The hereditary influence of the parents upon the resultant offspring is a well recognized factor in genetics. This factor is doubly important in forestry, not only in the collection of seed for artificial regeneration, but also in the selection of seed trees to provide for the natural reproduction of cut-over forests.

SILVICULTURAL ASPECT OF MISTLETOE INFECTION

The large amount of damage which is being done by the yellow pine mistletoe has been most strikingly shown during the progress of this study. Mistletoe presents one of the most serious problems in the rational silvicultural management of the forests of the Southwest. Now that the development and perfection of fire protection on the National Forests of the Southwest has reduced the fire hazard to a relatively small amount, the destruction from disease promises to approach or even surpass the losses from fire.

It is inevitable that the forests will comtinually sustain certain comparatively small losses from lightning fires and a certain amount of unpreventable windfall. On the other hand, much of the loss due to mistletoe injury can be prevented and ultimately after the lapse of several rotations these losses should be reduced to a comparatively small amount. The mistletoe may be slow in effecting its injury, but it is unquestionably certain.

A brief discussion of some of the salient principles of silviculture is deemed essential to a complete understanding of the significance of any methods of control which may be promulgated. The chief fundamentals of silviculture to be applied in the regeneration of western yellow pine stands are to maintain the continuity of the forest and to increase its productivity. The junior writer[9] has previously called attention to the fact

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[9] Korstian, C. F., Hewn-Tie Versus Saw-Timber Rotations. Proceedings of the Society of American Foresters 11: 315-329, 1916.

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that the pathological aspect should be considered fully in formulating a silvicultural management policy for any forest. It is evident therefore, that the chief object of forest regulation is the continuous maximum production of sound healthy timber. Such basic principles as the silvics of the species, the removal of the decadent, unhealthy and overmature timber as rapidly as possible to avoid waste through decay, the fire hazard and liability, exploitation and economic conditions must be taken into consideration under any rational method of cutting. All defective, diseased and suppressed trees should be marked for cutting unless needed as fire insurance or seed trees. However, a defective or diseased tree should not be left standing if it is evident that it will not live until the next cutting unless it is absolutely required for silvicultural purposes. When it becomes necessary to reserve trees among the larger diameter classes, thrifty, healthy trees of good form should be selected, since the condition of the resultant progeny is influenced by

heredity as well as by soil and climate. The tendency toward increased forest productivity will be realized if in the application of the above principles, the forester will strive to favor merchantable appreciation and eliminate the deterioration of merchantable material. It is thus evident that the marking on each individual acre must be varied to meet the silvicultural requirements of the forest. The importance of careful, intelligent marking on timber sale areas cannot be over-estimated since this, the most important of the silvicultural activities, is the practicable means by which rational silvicultural management is actually secured. Trees left standing for seed production or fire insurance should be protected as much as possible from mechanical injuries during the logging operation.[10]

[10] D. K. Noyes is authority for the statement that he found mistletoe on a 36-inch western yellow pine tree on the Stanislaus National Forest in California, developing in a scar made by an axe at the time the stand was logged over 5 years previous.

Meinecke[11] has suggested the establishment of patho-

[11] Meinecke, E.P. Forest Pathology in Forest Regulation, U. S. Dept. of Agri. Bull. 275, p. 59, 1916.

logical rotations for species of economic importance which are subject to serious diseases. A pathological rotation may be defined as the period during which the timber crop may grow and be subject to exploitation at a profit, but beyond which rapid deterioration is imminent and the product will be marketed at a great reduction in value. The pathological rotation may also be termed the age of decline or the age at which the trees become subject to heavy infection because they are unable to throw off or to hold the growth of the parasite in check. From the discussion in the earlier part of this paper it will be seen that the mistletoe may kill small seedlings only a few years old as well as old mature veteran yellow pines two or three hundred years old. It is, therefore, evident that it would be impossible to attempt to establish a pathological rotation for mistletoe-infected western yellow pine.

CONTROL OF MISTLETOE

It is evident from the preceding pages that the mis-

tletoe is one of the most serious and widely distributed enemies of the forests of the Southwest. Any method of control which may be promulgated must be adapted to existing conditions. Expensive and intensive measures such as pruning cannot be adopted in the vast forests of the western United States as in the much smaller and more intensively managed European forests. Just as in the cases of other diseases, prevention is the basis for the control of mistletoe. The protection of healthy stands of timber from disease is accomplished by removing the source of infection.

Mistletoe is more susceptible to control measures than many fungi. Mistletoe infection is confined to the aerial parts of the host while fungi and bacteria may infect the subterranean as well as the aerial parts. The seeds of the mistletoe which are much larger than the microscopic spores of fungi, are not subject to as wide dissemination as the latter. Mistletoe is killed with the death of its host whereas certain fungi may

remain alive for an indefinite period following the death of their hosts.

All of the facts at hand indicate that the heavy cutting of the mistletoe-infected trees is the only practicable method of control although it is very doubtful if the removal of lightly-infected trees would be warranted because of silvicultural reasons. The general marking rules for western yellow pine in the Southwest contain the following governing principles:

> Since western yellow pine stands vary so greatly, there can be no hard and fast rules as to the amount of timber to be left after the first cutting, and every area marked for cutting should be made the subject of a careful study from the point of view of both the silviculturist and the lumberman. The first object should be to leave enough trees to insure protection and seed, with the smallest loss of merchantable timber; for it must be borne in mind that if mature trees are left many of them will be lost through windfall or decay before the second cutting can be made.
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> Yellow pines which have passed the period of rapid growth should be marked for cutting except where required as seed trees or to afford protection or shelter for the establishment of reproduction. Black jacks and other rapidly growing intermediate trees in the transition stage between the black jack and the yellow pine forms should be left to provide for the next cut, except where, by thinnings, increased growth of the trees left can be obtained.
>
> A matter of prime importance is the distribution of the trees left after cutting. The aim should be to leave trees where they are needed, and not merely leave a certain number of seed trees per acre. Where there

are large natural openings, a number of seed-bearing trees should be left on the borders, especially on the windward side, but where there are good stands of poles beyond danger from fire no mature trees should be left. Of course, where there is still a fire risk, a sufficient number of old trees should remain as fire insurance trees to secure reproduction in case of a general conflagration.

Trees of the young and intermediate age classes should be uniformly reserved as far as possible. This will apply rational silviculture more effectively, both as to the securing of reproduction after cutting and as to insuring a second cut within a reasonable period when the shelterwood should be removed and the new growth liberated. The leaving of trees of the intermediate age class will distinctly better the opportunities for success in both of these respects. Furthermore, from the broad standpoint of the increase in the value of trees of this age class both through additional growth and increased stumpage prices, it is distinctly desirable to leave as much of this timber as possible.

The rule should be to leave trees of the intermediate age class unless some strong technical reason exists for their removal. The presumption of the marking officer should be to leave them and not to cut them. The reasons which would justify their cutting are: (1) Freeing the crowns of black jack or well established advance young growth underneath trees of this age class. Where the new stand has already been established, the leaving of such trees is obviously unnecessary for a shelterwood, and any gain in their growth will doubtless be more than offset by the increment of the young trees freed by the cutting of the intermediate trees above them; (2) serious disease or defects which indicate early death; (3) serious exposure to windthrow.

In the past there has been a tendency to underestimate the significance of the mistletoe injury. When the rules were promulgated, the cutting of diseased or defective trees was not permitted to break up or even to any extent reduce the shelterwood

or interfere with a uniform distribution of the cover on cut-over areas. This rule was applied to trees infected with mistletoe to the extent that the cutting of mistletoe-infected trees was not permitted to break up the continuity of the cover of the cutting area. Unless a tree of the intermediate age class was dying from mistletoe or was so completely infected that its early death was imminent it was left standing. The policy was to cut mistletoe-infected trees only when the infection was serious, since it was thought that a small or moderate amount of mistletoe would not injure the tree for many years.

The damage from mistletoe has proven more serious than was anticipated. The results indicate that all moderately and heavily infected trees should be removed at the time of the first cutting on the area. As has been indicated in the preceding pages, it is evident that mistletoe develops rapidly after cutting, since many of the trees left standing were killed by the mistletoe during the five years following the logging operation and many more, although still alive, will die in the course of only a few years.

It should be remembered that during the 5-year period from 1909 to 1914, as many as 7.5 per cent of the black jacks on the permanent sample plot of 456 acres on the Tusayan National Forest were killed by mistletoe alone or in conjunction with other agents the principal of which was insects. Mistletoe is regarded as being directly or indirectly responsible for the greater number of deaths of western yellow pine in which it appears as only one of several contributing causes.

The opening of the stand following a cutting operation stimulates the growth of the light-loving mistletoe through providing more favorable light conditions for the optimum development of the parasite. The increased activity of the mistletoe following the opening of the stand, militates against leaving standing for a future cutting operation any but lightly mistletoe-infected trees, the infection of which is confined to the lower portion of the crown. All other mistletoe-infected western yellow pine trees should be marked regardless of whether openings are created in the

forest cover. Old and heavily-infected trees should be cut for two reasons (1) to improve the hygienic condition of the forests of the future and (2) to secure the maximum realization on a rapidly depreciating forest capital. The policy of marking for cutting only the heavily infected trees and leaving the moderately infected trees with the idea that they will continue to grow and to normally mature into merchantable timber should be modified to provide for a heavier cutting of all but the more lightly infected trees. The argument has been advanced that the strict application of this modification of the marking instructions in regard to ridding the stands of mistletoe-infected trees would result in the disruption of the shelterwood where, in the semi-arid Southwest, it is of special importance. Every effort should be made toward the eradication of the mistletoe regardless of whether the stand is cut by the shelterwood, group-selection, selection, scattered seed tree or even the clear cutting silvicultural system of regeneration. In many cases it might even be greater silvicultural economy to clear cut and plant limited

areas at a cost of $15 to $20 per acre than to attempt to secure natural reproduction and in so doing permit the spread of a virulent parasite. Since the future productivity of the forest depends to a great extent upon the proper choice of seed trees or of the seed itself in the case of forestation work, those trees used for reproductive purposes should be sound, healthy and of an intermediate age class.

Weir[12] has suggested that the areas of mistletoe infection be located and mapped as a prerequisite to an efficacious

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[12]Weir, James R. Some suggestions on the Control of Mistletoe in the National Forests of the Northwest. Forestry Quarterly 14: 567-577, 1916.

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control campaign. The degree of parasitism and the amount of infection should also be recorded. This could easily be done by timber survey parties in connection with their regular mapping and cruising work. Such tangible records of mistletoe infections would be invaluable to Forest officers in showing just where diseased stands are located in order that attempts be made to

exploit stands of seriously diseased timber as rapidly as possible.

The advent of a large commercial timbersale operation should not be awaited before undertaking mistletoe control work. Small ranger sales and even the issuance of free use permits should materially assist in the reduction of severe infections. Although in many instances the large lumbering operation is more economical than the small one, the latter can render a definite service in improving the hygienic condition of the forest through removing more or less isolated infections which are too small to be exploited in a large operation. The products of the small operation are not marketed in as highly-finished or specialized form as are many of the products of the large operation. In the case of a small lumbering operation mistletoe-infected trees will, in almost every case, be as well adapted to the same uses as the products of healthy trees. Forests in the vicinity of nurseries and planting areas should present unusually healthy conditions. It should be remembered that healthy trees cannot

be grown in an insanitary environment. Healthy, thrifty progeny cannot be obtained from diseased, weak or aged parents.

In case a proposed timbersale area contains a great amount of mistletoe, a special mistletoe sanitation clause should be inserted in the contract, containing the stipulation that all moderately or heavily mistletoe-infected trees, whether merchantable or unmerchantable, should be felled. If the amount of unmerchantable infected timber were sufficient to materially affect the stumpage price, this factor should be fully taken into consideration and due allowance made for it in the stumpage appraisal.

In control work on those areas where both mistletoe and insects are present it would be advisable to combine the eradication of both pests wherever the present or future commercial value of the stand would justify such measures. Infestations of secondary bark borers have occasionally been found and reported with or immediately following mistletoe infection.[13]

[13] Hopping, Ralph. Insect Infestation in Relation to Injury, Fungi, and Mistletoe. Manuscript Report, February 24, 1915.

It is believed that certain of these insects even show a slight preference for trees attacked by mistletoe. The attack of trees weakened by the mistletoe often hastens their death or in the case of dead trees the work of the borers hastens deterioration. The control of such combined infections and infestations by eliminating the weakened trees would tend to control both mistletoe and insects as well as further the cause of the ultimate ideal - a productive, thrifty and healthy forest.

The yellow pine mistletoe probably has few natural enemies which can contribute toward its control. During the course of the studies reported in the preceding pages a spittle insect (Clastoptera obtusa)[14] was very frequently found within masses of

[14] Determined by Mr. E. H. Gibson, Scientific Assistant, Bureau of Entomology, U. S. Department of Agriculture.

spittle on the yellow pine mistletoe plants. The work of the insect in controlling the mistletoe is probably of little practical importance. However, since the insect subsists on the juices of the mistletoe it must tend to weaken its host to a certain extent,

especially in cases of severe infestations.

Through a proper realization and appreciation of the necessitity for adopting adequate control measures on all cutting areas where the amount of mistletoe infection is relatively great a good beginning can be made toward the eradication of the pest through the more or less gradual process of elimination.

SUMMARY

Western yellow pine is subject to severe injury by the yellow pine mistletoe (Razoumofskya cryptopoda). The injury to the forest caused by the insidious and destructive action of this pest can scarcely be over-emphasized.

Mistletoe infection causes a marked decrease in the rate of growth of the host, which continues until ultimately the parasite causes the death of the tree. The rate of decrease varies directly with the degree of infection from a very marked falling off in the current growth of heavily-infected trees to a very slight or no decrease in the growth of lightly-infected trees. Many trees are killed annually by this pest alone or in conjunction

with other causes such as insect infestations or porcupine injury.

The decrease in the rate of diameter and height growth and consequently the current increment is caused by a reduction of the leaf surface of the tree.

Trees of all age classes are subject to mistletoe infection provided the seeds of the parasite fall on parts of the tree which are not protected by the suberized cortex. Young seedlings and saplings usually die comparatively soon after becoming severely infected while older trees may live for a much longer time before they die.

The quantity and quality of the seed produced by trees infected with mistletoe is far below that of normal healthy trees. Heavily-infected trees are practically worthless for seed production and should not be left as seed or fire insurance trees for the purpose of regenerating the forest.

The most practical method of controlling mistletoe is to remove the infected trees in all cutting operations. Moderately

and heavily-infected trees should be marked for cutting.

When proposed timbersale areas contain a great amount of mistletoe a sanitation clause should be inserted in the timbersale contract requiring the cutting of all moderately or heavily-infected trees, whether marchantable or unmerchantable.

TABLE 1 - Monthly summaries of climatological data in Western Yellow pine forest at Fort Valley Experiment Station, Arizona.

Mean 1909-1916	Air Temperature			Mean Soil Temperature[2]	Total Precipitation	Mean Relative Humidity	Mean Daily Wind Movement	Total Evaporation from free water surface
	Mean Maximum Deg. F.	Mean Minimum Deg. F.	Mean[1] Deg. F.	Degrees F.	Inches	Per Cent	Miles	Inches
January	38.9	13.7	26.3	33.3	2.92	67.4	56.92	-
February	40.9	14.0	27.4	34.9	1.83	62.0	61.64	-
March	46.9	20.6	33.7	35.2	2.42	62.6	65.37	-
April	54.6	26.0	40.3	38.9	0.99	49.4	75.56	-
May	64.3	30.4	47.3	42.5	0.52	38.5	79.29	6.00
June	74.5	38.4	56.5	50.2	0.48	35.5	76.12	7.15
July	75.8	47.0	61.4	55.2	3.27	58.0	52.63	5.30
August	75.3	46.5	60.9	56.7	2.77	62.0	47.78	4.70
September	69.9	39.2	54.5	55.0	1.38	56.4	56.55	3.97
October	60.0	28.4	44.2	48.5	1.86	56.1	60.34	2.70
November	51.5	21.6	36.4	41.6	0.76	62.2	56.73	-
December	38.8	11.6	25.2	36.2	1.88	60.3	55.05	-
Total ..					21.08			29.82
Mean Annual	57.6	28.1	42.8	44.0	-	54.9	61.83	

[1] Mean maximum + mean minimum ÷ 2.

[2] Soil temperature readings were taken at a depth of 2 feet.

TABLE 2 -- Comparison of the average diameter growth or accretion of 58 standing black jacks, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Diameter Breast High		Accretion, 1910-1915		Basis
	1910	1915	Periodic	Periodic Annual	
	Inches	Inches	Inches	Inches	No. of Trees
0	16.16	16.97	.81	.16	27
x	17.65	18.63	.98	.20	6
xx	15.82	16.57	.75	.15	15
xxx	14.24	14.36	.12	.02	10

TABLE 3 -- Comparison of the average diameter growth or accretion of 33 standing yellow pines, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Diameter Breast High		Accretion, 1910-1915		Basis
	1910	1915	Periodic	Periodic Annual	
	Inches	Inches	Inches	Inches	No. of Trees
0	24.60	25.30	.70	.14	9
x	25.56	26.04	.48	.10	8
xx	22.14	22.44	.30	.06	7
xxx	21.49	21.61	.12	.02	9

TABLE 4 -- Comparison of the total volume growth or increment of 58 standing black jacks, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Total Volume		Increment, 1910-1915			Basis
	1910	1915	Periodic	Periodic Annual		
	cu.ft.	cu. ft.	cu.ft.	cu.ft.	per cent	No. of Trees
0	987.2	1100.9	113.7	22.7	2.30	27
x	291.4	324.4	33.0	6.6	2.26	6
xx	434.0	470.6	36.6	7.3	1.60	15
xxx	234.9	243.2	8.3	1.7	.71	10

TABLE 5 --Comparison of the total volume growth or increment of 33 standing yellow pines, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Total Volume		Increment, 1910-1915			Basis
	1910	1915	Periodic	Periodic Annual		
	cu.ft.	cu. ft.	cu.ft.	cu.ft.	per cent	No. of Trees
0	1151.0	1226.0	75.0	15.0	1.30	9
x	1206.0	1250.0	44.0	8.8	.73	8
xx	706.0	725.0	19.0	3.8	.54	7
xxx	801.0	809.0	8.0	1.6	.20	9[1]

[1]Five trees of this class died during the 5-year period and were not included in this computation.

TABLE 6 -- Comparison of the average diameter growth or accretion of 33 standing black jacks, for a 5-year period, at 4.5, 17 and 33 feet from ground, grouped according to degree of mistletoe infection.

Degree of Infection	Diameter 1911			Diameter 1916			Accretion 1911 - 1916, Periodic			Accretion 1911 - 1916, Periodic Annual			Basis
	4.5 Ft.	17 Ft.	33 Ft.	4.5 Ft.	17 Ft.	33 Ft.	4.5 Ft.	17 Ft.	33 Ft.	4.5 Ft.	17 Ft.	33 Ft.	
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	No. of Trees.
0	17.93	15.28	12.69	19.03	16.30	13.71	1.10	1.02	1.02	.22	.20	.20	16
x	22.25	19.59	14.14	23.40	20.85	15.25	1.15	1.26	1.11	.23	.25	.22	4
xx	15.92	13.20	8.65	16.78	13.81	9.46	.86	.61	.83	.17	.12	.16	7
xxx	16.47	14.42	9.19	17.15	14.64	9.31	.68	.22	.12	.13	.04	.02	6

TABLE 7 -- Comparison of the total volume growth or increment of 33 standing black jacks, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Total Volume 1911	Total Volume 1916	Increment, 1911-1916, Periodic	Increment, 1911-1916, Periodic	Increment, 1911-1916, Annual	Basis
	cu.ft.	cu.ft.	cu.ft.	cu.ft.	Per cent	No. of Trees
0	919.76	1047.40	127.64	25.53	2.77	16
x	359.07	410.65	51.58	10.32	2.87	4
xx	286.83	316.08	29.25	5.85	2.03	7
xxx	262.65	273.97	11.32	2.26	.85	6

TABLE 8 -- Basic data for 107 felled trees showing the effect of mistletoe on the growth and seed production of western yellow pine.

Tree No.	Age	Diameter breast high	Diameter growth for last 5 years	Total height	Height growth for last 5 yrs.	Total Volume	Volume growth for last 5 yrs.	Degree of Infection[1]	Crown Class[2]	Average length of leaves	Average length of leaf tufts	Seed Crop 1915[3]
	Yrs.	Ins.	Ins.	Ft.	Ft.	Cu. ft.	Cu. ft.			Ins.	Ins.	
58	23	4.0	1.5	16.5	4.5	1.81	.39	0	X	5.5	19.3	0
75	23	4.6	1.6	14.5	3.0	.84	.55	x	C	4.1	7.0	0
59	24	2.8	.7	13.5	3.5	.27	.08	0	C	5.6	19.3	0
74	24	3.2	1.0	13.5	3.5	.36	.17	0	C	5.1	11.6	0
67	25	1.9	.4	9.0	1.0	.11	.03	xx	S	2.6	5.0	0
62	26	2.4	.6	13.5	3.0	.22	.11	0	C	4.0	9.6	0
70	26	2.0	1.0	11.5	3.5	.12	.06	0	D	5.1	9.0	0
85	27	-	-	3.1	.5	.01	.001	xxx	S	3.0	3.2	0
72	28	2.4	1.2	11.5	4.0	.19	.09	0	D	6.0	10.3	0
73	28	6.2	1.8	24.5	4.5	2.02	.99	0	C	5.8	11.3	0
86	29	-	-	3.2	.8	.021	.014	xxx	X	5.6	6.3	0
84	29	-	-	2.8	.3	.009	.001	xxx	S	2.8	3.4	0
60	30	8.4	.6	23.5	3.0	1.58	.47	x	D	4.1	10.0	0
69	30	1.9	.4	9.5	2.0	.09	.01	x	I	3.3	4.3	0
71	30	5.4	1.6	17.5	4.0	.88	.33	0	C	5.6	11.3	0
82	30	4.8	1.8	17.5	4.5	.98	.63	0	D	5.6	23.3	0
45	31	4.6	1.0	17.5	3.0	.80	.29	x	C	4.1	8.6	0
15	31	-	-	3.5	1.0	.07	.06	x	X	3.0	9.3	0
38	32	3.8	.2	10.5	1.0	.41	.13	xx	X	2.1	3.3	0
17	33	-	-	3.0	.5	.01	.002	xx	X	-	-	0
61	33	4.8	.5	16.0	1.5	1.06	.27	xxx	C	2.7	5.5	0
64	33	3.0	.5	13.5	2.0	.33	.13	xx	I	3.3	10.3	0
63	35	.5	.2	5.5	.5	.09	.02	xxx	I	2.3	3.0	0
66	35	4.0	1.2	17.5	3.5	1.03	.42	x	C	4.1	8.5	0
93	37	-	-	4.3	.7	.014	.022	xxx	X	3.1	2.8	0
107	37	7.1	-	21.0	-	2.40	-	0	D	5.2	8.5	0
18	39	5.1	1.1	18.0	3.0	1.78	.69	0	X	5.3	15.0	0
20	46	6.2	1.1	17.5	2.0	1.85	.63	xx	X	3.7	4.7	0
19	53	6.2	.8	27.0	3.0	3.11	1.05	x	X	5.6	17.0	0
29	60	15.6	1.5	47.5	3.5	21.24	5.06	0	X	6.8	13.3	0
47	65	13.2	1.6	51.5	6.0	19.79	4.69	0	C	5.3	8.0	L
81	65	10.8	1.3	46.0	4.5	11.28	3.38	0	C	5.8	22.5	0
82	66	9.0	.4	33.0	1.5	5.09	.76	xxx	C	4.1	6.6	0
58	66	11.2	.4	30.5	.5	8.14	.99	xx	X	3.5	5.0	0
89	66	7.9	.7	33.5	2.5	3.35	.72	x	X	4.0	7.7	0
48	69	10.8	1.1	39.0	2.5	9.09	2.11	xx	C	4.5	6.0	0
57	70	15.8	2.0	60.0	5.0	27.38	6.12	0	C	6.3	7.3	0
80	70	8.8	1.0	37.5	1.5	5.63	.94	0	S	6.6	7.5	0
88	71	7.5	.6	34.5	1.5	4.59	.47	x	C	4.3	6.7	0
8	72	4.4	.3	17.0	1.0	.85	.11	xx	I	5.6	-	0
46	72	15.6	1.1	45.5	3.0	19.84	3.89	0	X	5.1	10.6	0
37	74	7.0	.1	30.0	1.0	1.66	.08	xxx	X	3.5	3.1	0
21	75	7.4	.4	30.0	.5	3.77	.49	xxx	I	2.6	2.6	0
98	76	19.5	1.5	60.5	3.5	30.70	4.79	0	C	6.0	6.7	0
10	78	11.8	.4	36.5	.5	10.17	.67	xx	X	4.3	-	0
77	78	11.7	.5	36.5	.5	10.68	1.06	xxx	X	3.6	5.3	0
49	79	9.5	.3	33.5	1.0	5.47	.83	xxx	C	4.0	4.6	0
78	79	5.4	.4	26.0	1.0	2.08	.43	xx	S	3.5	4.3	0
104	79	14.5	-	42.0	-	13.00	-	0	S	3.8	6.5	L
1	80	12.6	.2	39.5	.7	14.60	1.13	xxx	X	-	-	0
11	80	10.0	1.6	34.5	3.5	7.02	2.21	0	X	6.3	15.0	0
103	80	7.5	-	20.0	-	2.50	-	xxx	S	2.8	4.2	0
5	82	8.0	.4	33.5	.5	5.91	.33	xxx	C	-	-	0
9	82	10.6	.2	44.5	.5	9.64	.43	xx	S	3.6	-	0
44	82	11.2	.6	39.0	2.5	9.07	1.56	x	C	4.3	5.0	0
90	82	6.9	.3	28.5	.5	2.46	.36	x	C	4.3	5.5	0
6	83	10.8	1.5	47.5	4.0	10.67	2.76	0	D	5.6	-	0
38	83	9.8	.2	37.5	.2	7.65	.30	xxx	X	3.3	5.0	0
105	83	6.1	-	26.0	-	3.55	-	xxx	C	3.5	4.2	0
106	83	15.2	-	49.0	-	23.50	-	0	C	5.8	6.1	L
54	84	7.1	.5	27.5	2.0	2.51	.37	xxx	C	4.3	4.6	0
43	85	8.2	.3	40.5	3.5	6.65	1.23	xx	C	4.1	5.0	0
51	85	14.4	1.2	47.5	3.0	21.19	5.62	0	C	5.6	8.0	0
24	87	11.1	1.6	41.5	4.0	10.93	2.04	0	S	6.0	22.0	0
79	88	5.8	.4	24.5	.5	1.57	.23	xxx	S	4.1	8.6	0
14	89	10.4	.5	35.5	2.0	7.84	.98	xxx	D	3.6	5.7	L
53	92	14.0	1.1	48.5	2.5	16.00	2.69	0	C	5.6	8.6	L
13	93	7.5	.2	32.5	.5	4.26	.37	xx	X	5.1	7.8	0
23	93	6.9	.1	29.5	1.0	2.30	1.80	xxx	C	3.1	3.3	0
91	93	8.9	.4	36.0	1.0	5.68	1.01	x	X	4.5	6.5	0
2	94	12.0	1.5	40.5	1.0	15.18	4.40	0	X	-	-	0
42	94	14.8	.2	41.5	.5	20.05	.67	xxx	X	4.5	5.6	0
76	94	9.8	.7	30.0	1.0	7.80	.77	xxx	C	3.1	4.6	0
7	95	4.0	.1	21.0	1.0	.84	.16	xxx	S	4.1	-	0
56	95	14.4	.3	42.5	1.0	16.27	.42	xxx	C	4.0	5.0	0
87	97	9.0	.5	43.0	1.0	7.06	.85	x	C	4.6	5.3	0
28	98	18.1	1.5	64.5	6.0	47.49	6.48	x	X	6.3	11.3	0
26	100	8.3	.2	30.0	.5	4.23	.28	xxx	D	4.5	3.6	0
55	100	14.6	.2	49.5	1.0	20.05	1.08	xxx	C	5.2	5.5	0
99	102	20.6	1.0	64.5	3.0	52.44	6.61	0	C	4.7	6.3	0
12	104	12.4	.5	41.5	1.5	13.23	1.17	0	S	5.3	6.1	0
93	104	21.6	1.1	73.0	3.5	63.47	5.73	0	C	4.8	5.7	L
95	105	20.4	.6	60.5	1.5	63.11	4.30	x	C	5.2	7.2	0
40	106	9.4	.8	53.0	3.0	8.62	.92	xx	C	5.3	6.6	0
39	112	11.6	1.2	62.0	3.5	18.82	3.89	0	C	5.0	10.6	0
96	114	18.8	.6	70.5	1.0	43.06	1.64	xx	C	4.3	6.8	0
94	117	20.4	1.0	78.0	3.0	69.85	5.06	0	C	5.1	6.2	L
45	120	19.4	.4	67.0	1.0	42.69	1.32	xx	C	4.3	5.6	0
97	120	22.4	1.7	79.5	2.5	83.56	11.32	0	C	5.4	6.8	L
41	121	11.9	.8	58.0	1.0	16.10	1.09	xxx	C	5.3	6.6	0
27	123	17.6	.1	45.5	.5	21.86	.50	xxx	X	4.6	6.1	0
4	124	20.2	1.7	66.5	1.0	67.68	9.40	0	S	6.0	9.0	0
92	125	17.1	.4	68.0	1.0	43.33	1.78	xx	C	5.1	6.0	0
3	126	20.3	.5	68.5	.3	42.03	1.49	xxx	X	4.0	2.5	0
60	130	23.4	2.3	79.5	1.5	92.78	8.56	0	D	5.0	6.3	M
26	134	18.2	.2	45.0	0.5	25.23	.82	xxx	S	3.6	2.5	0
16	138	20.2	.4	59.5	.5	50.01	2.74	x	X	6.1	11.5	0
36	214	19.2	1.2	67.5	1.5	44.90	4.27	0	C	5.6	7.1	L
102	214	23.0	1.4	85.0	1.0	108.50	7.98	0	D	5.5	5.3	L
33	217	18.2	.5	56.5	1.0	38.92	2.02	xxx	X	4.7	8.3	0
30	218	18.2	.4	75.5	.2	59.66	2.35	xxx	C	3.5	-	0
100	218	20.8	.5	77.5	1.5	71.98	2.63	0	C	5.3	5.2	L
101	218	25.6	1.3	87.5	1.0	133.67	10.17	0	X	4.8	5.0	0
31	220	16.0	.1	84.5	.5	54.91	1.16	xxx	C	5.0	7.1	M
32	220	21.6	.8	87.5	1.0	90.26	7.06	0	D	5.8	7.3	M
34	230	25.6	.4	78.5	.3	107.47	2.88	xxx	X	5.2	8.8	0
35	233	17.6	.2	72.0	.5	65.10	5.68	xxx	C	4.5	5.6	0

1 - Degree of infection classified as follows: 0 = healthy trees without mistletoe, x = light mistletoe infection, xx = medium mistletoe infection, xxx = heavy mistletoe infection.
2 - Crown class of trees classified as follows: X = Isolated, D = Dominant, C = Codominant, I = Intermediate, S = Suppressed.
3 - Seed crop classified as follows: H=Heavy, G = Good, M = Medium, L = Light, O = None.

TABLE 9 - Comparison of the average diameter growth or accretion of 102 felled western yellow pine trees, for a 25-year period, grouped by age classes and degree of mistletoe infection.

Age Class	Degree of Infection	Diameter breast high 1890	Diameter breast high 1895	Accretion 1890 - 95 Periodic Annual	Diameter breast high 1900	Accretion 1895-1900 Periodic Annual	Diameter breast high 1905	Accretion 1900-'05 Periodic Annual	Diameter breast high 1910	Accretion 1905 -'10 Periodic Annual	Diameter breast high 1915	Accretion 1910 -'15 Periodic Annual	Basis
Years		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	No. of Trees
21-60	0	.8	1.0	.04	1.6	.12	2.3	.14	3.7	.28	5.0	.26	11
	x	.2	.6	.08	1.4	.16	2.5	.22	3.5	.20	4.4	.18	6
	xx	.1	.4	.10	.8	.08	1.3	.10	1.8	.10	2.1	.06	7
	xxx	-	.3	.06	.6	.06	.7	.02	.9	.04	1.1	.04	5
61-100	0	7.2	8.2	.20	9.3	.22	10.4	.22	11.5	.22	13.0	.30	12
	x	6.6	7.3	.14	8.0	.14	8.7	.14	9.3	.12	9.9	.12	7
	xx	6.0	6.8	.16	7.5	.14	8.1	.12	8.6	.10	9.0	.08	9
	xxx	6.8	7.5	.14	8.2	.14	8.7	.10	9.2	.10	9.4	.04	17
101-140	0	15.0	15.7	.14	16.5	.16	17.5	.20	18.6	.22	19.8	.22	6
	x	14.5	15.1	.12	15.9	.16	16.7	.16	17.5	.16	18.3	.16	4
	xx	14.8	15.2	.08	15.7	.10	16.1	.08	16.5	.08	16.9	.08	6
	xxx	15.2	15.6	.08	15.9	.06	16.3	.08	16.7	.08	17.0	.06	4
01-240	0	17.8	18.5	.14	19.3	.16	20.1	.16	21.1	.20	22.1	.20	5
	xxx	16.7	17.0	.06	17.4	.08	17.7	.06	17.9	.04	18.2	.06	5

TABLE 10 - Comparison of the average height growth or accretion of 102 felled western yellow pine trees, for a 25-year period, grouped by age classes and degree of mistletoe infection.

Age Class	Degree of Infection	Total Height 1890	Total Height 1895	Accretion 1890-95 Periodic Annual	Total Height 1900	Accretion 1895-1900 Periodic Annual	Total Height 1905	Accretion 1900-05 Periodic Annual	Total Height 1910	Accretion 1905-10 Periodic Annual	Total Height 1915	Accretion 1910-15 Periodic Annual	Basis
Years		Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	No. of Trees
21-60	0	3.2	5.4	.44	8.0	.51	11.3	.66	14.9	.72	18.6	.74	11
	x	2.6	5.1	.50	8.3	.64	12.2	.78	15.3	.62	18.2	.58	6
	xx	1.6	3.2	.32	4.6	.28	6.1	.30	7.4	.26	8.6	.24	7
	xxx	1.3	2.5	.22	3.8	.26	4.9	.22	5.7	.16	6.3	.12	5
61-100	0	27.4	31.5	.82	35.6	.82	39.5	.78	43.2	.74	46.6	.68	12
	x	29.6	32.2	.52	34.6	.48	36.8	.44	38.8	.40	40.8	.40	7
	xx	23.7	26.1	.48	28.3	.44	30.5	.44	32.1	.32	33.3	.24	9
	xxx	26.4	28.4	.40	30.0	.32	31.2	.24	32.2	.20	33.0	.16	17
01-140	0	58.9	61.5	.52	64.2	.54	66.9	.54	69.7	.56	72.5	.58	6
	x	49.4	51.8	.48	53.5	.34	55.0	.30	56.4	.28	57.5	.22	4
	xx	55.8	57.9	.42	60.0	.42	61.9	.38	63.5	.32	65.0	.30	4
	xxx	46.4	47.8	.28	49.0	.24	50.0	.20	50.6	.12	51.2	.12	4

TABLE 11 - Comparison of the average volume growth or increment of 102 felled western yellow pine trees, for a 25-year period, grouped by age classes and degree of mistletoe infection.

Age Class	Degree of Infection	Total Volume 1890	Total Volume 1895	Increment 1890-95 Periodic Annual	Increment 1890-95 Per cent	Total Volume 1900	Increment 1895-1900 Periodic Annual	Increment 1895-1900 Per cent	Total Volume 1905	Increment 1900-05 Periodic Annual	Increment 1900-05 Per cent	Total Volume 1910	Increment 1905-10 Periodic Annual	Increment 1905-10 Per cent	Total Volume 1915	Increment 1910-15 Periodic Annual	Increment 1910-15 Per cent	Basis No. of Trees
Years		Cu.ft.	Cu.ft.	Cu.ft.		Cu.ft.	Cu.ft.		Cu.ft.	Cu.ft.		Cu.ft.	Cu.ft.		Cu.ft.	Cu.ft.		
21-60	0	.36	.54	.036	[1]	.80	.052	[1]	1.19	.078	[1]	1.81	.124	[1]	2.67	.170	[1]	11
	x	.02	.05	.007		.20	.030		.41	.042		.86	.090		1.25	.078		6
	xx	.01	.02	.010		.08	.012		.14	.012		.24	.020		.37	.026		7
	xxx	-	-	-		.04	.008		.08	.008		.18	.020		.29	.022		5
61-100	0	3.77	5.40	.326	8.6	7.54	.428	7.9	10.23	.538	7.1	13.52	.658	6.4	17.28	.752	5.6	12
	x	4.90	5.91	.202	4.1	7.10	.238	4.0	8.49	.274	3.9	9.89	.280	3.3	11.49	.320	3.2	7
	xx	2.53	3.24	.138	5.4	3.98	.148	4.6	4.81	.166	4.1	5.65	.168	3.5	6.52	.174	3.1	9
	xxx	4.12	4.94	.164	3.9	5.72	.156	3.2	6.46	.148	2.6	7.12	.102	2.1	7.70	.106	1.6	17
101-140	0	35.10	39.78	.936	2.7	44.80	1.004	2.5	50.26	1.092	2.3	56.48	1.244	2.4	63.41	1.386	2.4	6
	x	25.95	30.15	.840	3.2	34.80	.930	3.1	39.20	.880	2.5	43.72	.904	2.3	48.07	.870	2.0	4
	xx	23.72	26.36	.526	2.2	28.62	.454	1.7	30.75	.424	1.5	32.70	.390	1.3	34.60	.380	1.1	4
	xxx	20.02	21.04	.276	1.4	22.87	.294	1.4	24.10	.246	1.1	25.32	.244	1.0	26.42	.220	.9	4
201-240	0	59.06	63.94	.976	1.7	69.38	1.088	1.7	75.72	1.268	1.8	82.46	1.348	1.8	90.12	1.532	1.9	5
	xxx	52.16	54.36	.440	.8	56.56	.440	.8	58.94	.476	.8	61.38	.488	.8	64.00	.524	.8	5

1. The periodic annual increment per cent was not computed for age class 21-60, because of the extremely small initial volumes and the proportionately rapid rate of increase in volume.

TABLE 12-Comparison of the average diameter growth or accretion of 54 limbs on 18 standing black jacks, for a 5-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Average Diameter[1] 1910	Average Diameter[1] 1915	Accretion, 1910-1915 Periodic	Accretion, 1910-1915 Periodic Annual	Basis No. of limbs.
	In.	In.	In.	In.	
0	3.84	3.98	.14	.028	20
x	3.90	4.06	.16	.032	6
xx	4.35	4.62	.27	.054	7
xxx	4.08	4.46	.38	.076	21

1. Average of two sets of measurements taken at 6 and 18 inches from the hole of the tree.

TABLE 13 - Comparison of the average diameter growth or accretion of 8 limbs on 4 felled western yellow pine trees, for a 25-year period, grouped according to degree of mistletoe infection.

Degree of Infection	Average Diameter[1] 1890	Average Diameter[1] 1895	Accretion 1890-95 Periodic Annual	Average Diameter[1] 1900	Accretion 1895-1900 Periodic Annual	Average Diameter[1] 1905	Accretion 1900-05 Periodic Annual	Average Diameter[1] 1910	Accretion 1905-10 Periodic Annual	Average Diameter[1] 1915	Accretion 1910-15 Periodic Annual	Basis. No. of Limbs
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	
0	1.68	1.84	.032	2.01	.034	2.21	.04	2.34	.026	2.46	.024	4
xxx	3.06	3.32	.052	3.68	.072	4.04	.072	4.34	.060	4.56	.044	4

TABLE 14 - Comparison of the length of leaves of 103 western yellow pine trees, classified according to degree of mistletoe infection.

Degree of Infection	In Lower Portion of Crown			In Center Portion of Crown			In Upper Portion of Crown			Mean for Entire Crown			Basis
	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	No. of Trees
0	3.3	6.2	4.9	3.8	6.3	5.5	4.2	6.9	5.8	3.8	6.5	5.4	38
x	2.3	5.3	4.0	2.5	5.9	4.5	3.3	6.2	5.0	2.7	5.8	4.5	15
xx	2.1	5.3	3.8	2.5	5.4	4.1	2.9	5.7	4.6	2.5	5.5	4.2	18
xxx	2.1	5.1	3.6	2.4	5.1	4.0	2.7	5.1	4.0	2.4	5.1	3.9	32

TABLE 15 - Comparison of the length of leaf tufts of 97 western yellow pine trees, classifed according to degree of mistletoe infection.

Degree of Infection	In Lower Portion of Crown			In Center Portion of Crown			In Upper Portion of Crown			Mean for Entire Crown			Basis
	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	Mean Min.	Mean Max.	Aver.	
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	No. of Trees
0	3.4	11.5	6.7	5.4	15.5	10.0	6.8	22.7	13.8	5.2	16.6	10.2	37
x	3.0	10.1	6.5	4.0	12.0	8.0	5.5	16.8	10.3	4.2	13.0	8.3	15
xx	2.4	8.2	4.9	2.3	9.1	5.2	3.4	11.1	7.3	2.7	9.4	5.8	15
xxx	2.3	8.1	4.5	2.6	8.6	5.0	2.4	8.5	4.8	2.4	8.4	4.8	30

Table 17. Classification of dead trees on permanent sample plots of 456 acres on the Tusayan and 135 acres on the Coconino National Forest showing the mortality of western yellow pine with mistletoe the direct cause or a contributing factor.

Cause of Death	Per Cent of Dead Trees 1909-1914 (Based on total number of trees which died during 5-year period)			
	456 acre Plot Tusayan National Forest		135 acre Plot Coconino National Forest	
	Black Jack	Yellow Pine	Black Jack	Yellow Pine
	Per Cent	Per Cent	Per Cent	Per Cent
Mistletoe	26.4	[illegible]	7.5	7.9
Mistletoe and Insects	35.0	[illegible] 4.8	[illegible]	20.2
Mistletoe and Porcupine	5.5			
Mistletoe and Suppression	1.4			
Mistletoe Porcupine, Insects	.4			
All other Causes	31.3	95.2	92.5	71.9
Total	100.0	100.0	100.0	100.0

TABLE 18 - Data on the seed production of 64 felled western yellow pine trees classified according to degree of mistletoe infection.

Degree of Infection	Final Germination	Clean Seeds Per Pound	Yield per Tree		Reproductive Value Per Tree	Basis
			Cones	Clean Seed		
	Per Cent	Number	Bushels	Pounds	No. of Viable Sds	No. of Trees
1913 Collection						
0	82.8	14,473	0.8	1.08	12,942	43
x	84.1	14,385	1.0	1.10	13,292	2
xx	81.7	13,314	0.5	0.45	4,895	2
xxx	77.0	14,475	0.3	0.31	3,455	2
Mean of x, xx & xxx	80.9	14,058	0.6	0.62	7,052	6
1915 Collection						
0	53.2	12,156	1.1	0.87	5,626	11
Mean of x, xx & xxx	47.1	14,170	0.9	0.33	2,202	4

TABLE 19 - Record of 1912 and 1915 seed crops for 177 standing western yellow pine trees classified by degree of mistletoe infection and amount of seed crop.

Degree of Infection	Amount of seed Crop										Total Basis
	Heavy		Good		Medium		Light		None		
	No. of Trees	Per Cent	No. of Trees	Per Cent	No. of Trees	Per Cent	No. of Trees	Per Cent	No. of Trees	Per Cent	No. of Trees
				1912 Seed Crop							
0	0	0	0	0	2	5.3	9	23.7	27	71.0	38
x	1	7.7	0	0	1	7.7	4	30.8	7	53.8	13
xx	0	0	0	0	0	0	5	25.0	15	75.0	20
xxx	0	0	0	0	0	0	0	0	16	100.0	16
				1915 Seed Crop							
0	0	0	1	2.8	2	5.5	15	41.7	18	50.0	36
x	0	0	0	0	2	14.3	5	35.7	7	50.0	14
xx	0	0	0	0	0	0	4	18.2	18	81.8	22
xxx	0	0	0	0	0	0	0	0	18	100.0	18

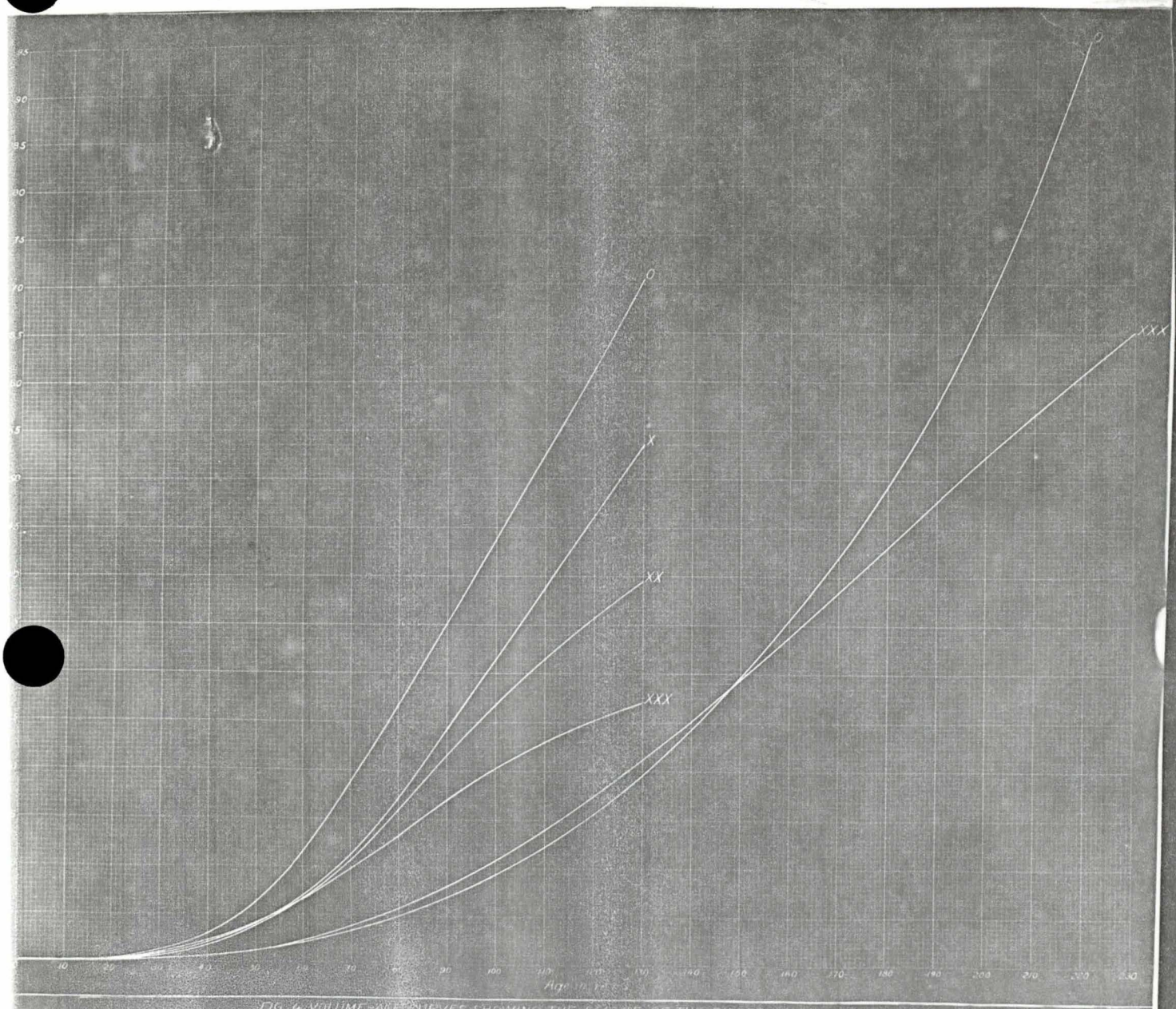


FIG 4 VOLUME-AGE CURVES SHOWING THE EFFECT OF THE DIFFERENT DEGREES OF MISTLETOE INFECTION ON THE 101-140 AND THE 201-240 YEAR AGE CLASSES

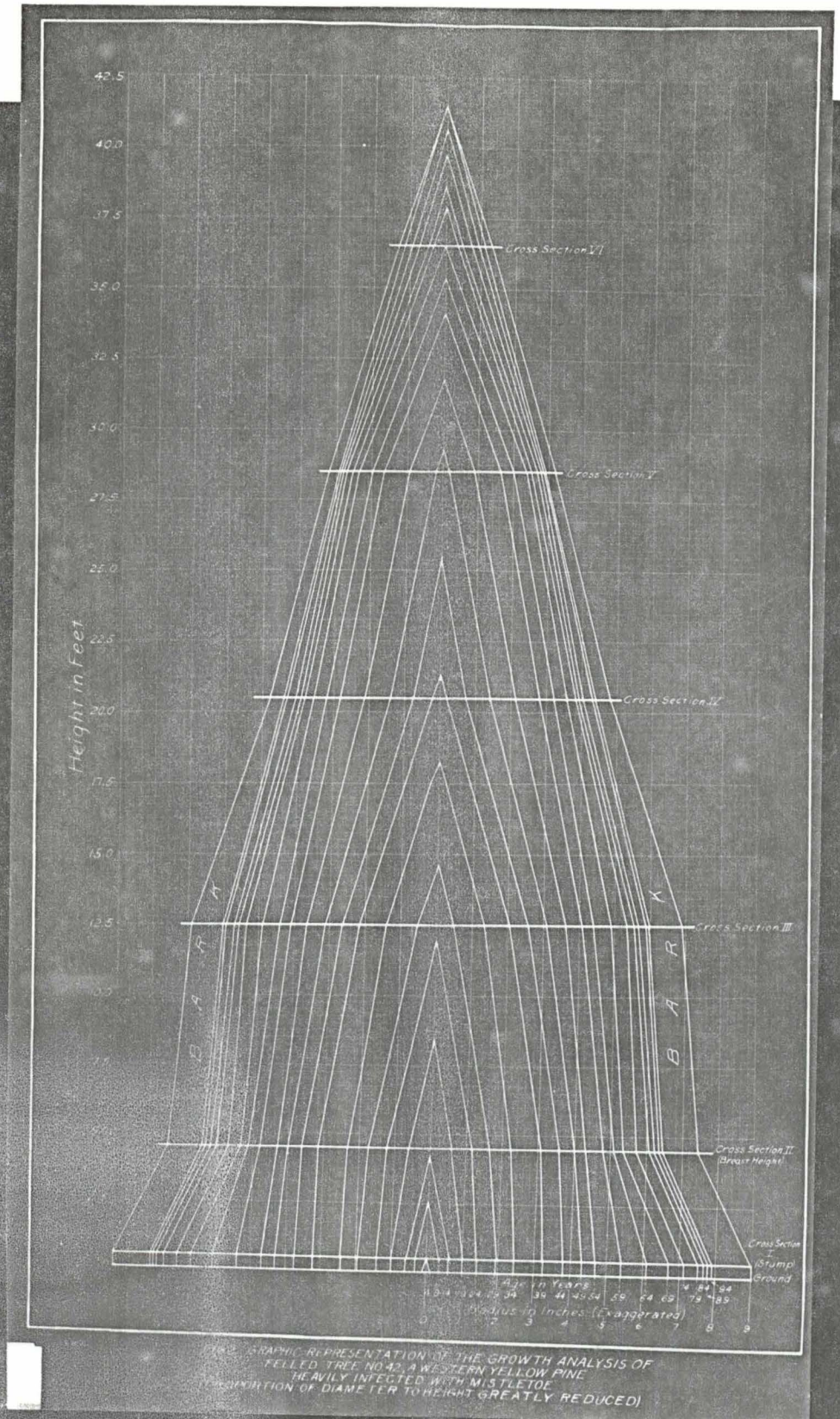
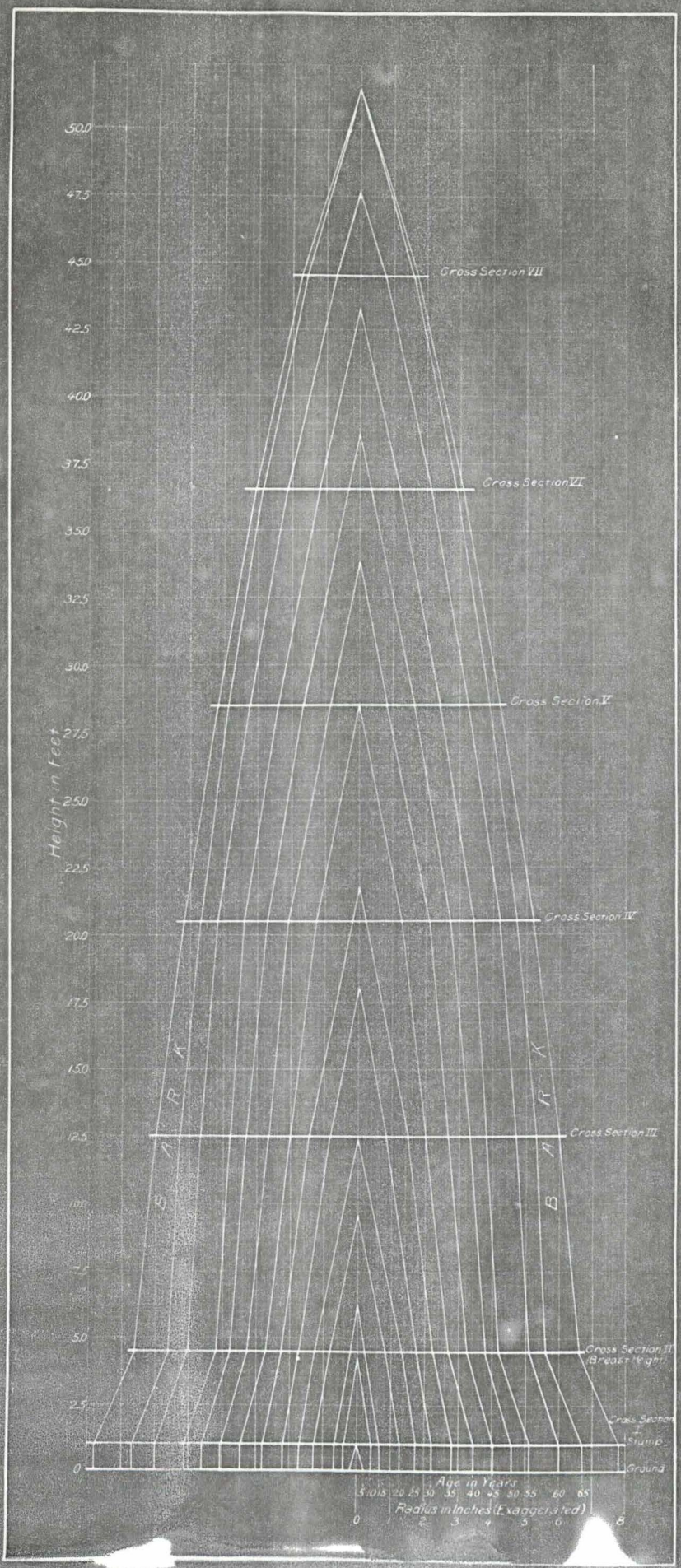


FIG. 2. GRAPHIC REPRESENTATION OF THE GROWTH ANALYSIS OF FELLED TREE NO 42, A WESTERN YELLOW PINE HEAVILY INFECTED WITH MISTLETOE (PROPORTION OF DIAMETER TO HEIGHT GREATLY REDUCED)



PHOTOGRAPHIC REPRESENTATION OF LIFE GROWTH ANALYSIS OF FELLED TREE NO. 47, A SUNDERLAND WESTERN YELLOW PINE

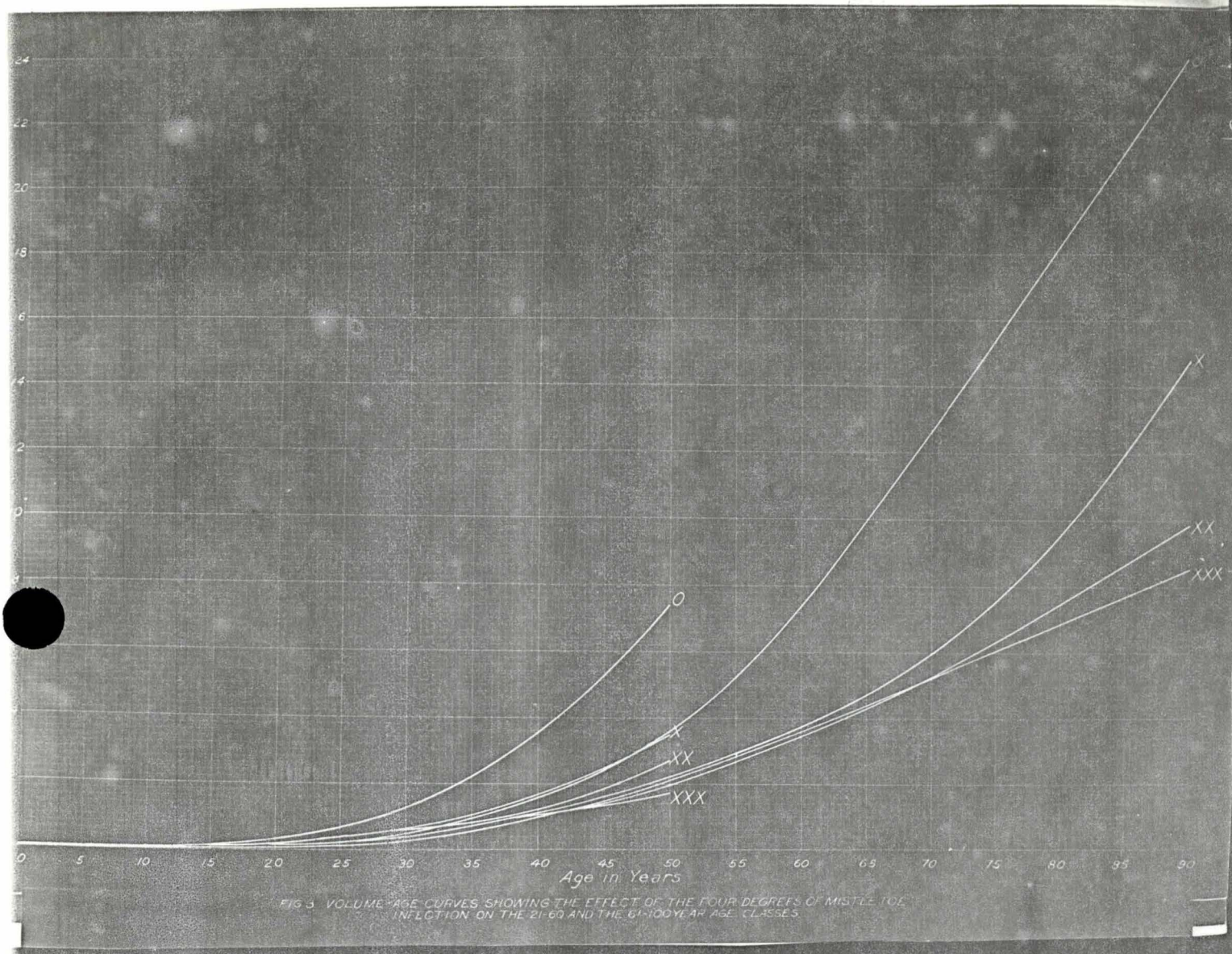


FIG 3 VOLUME-AGE CURVES SHOWING THE EFFECT OF THE FOUR DEGREES OF MISTLETOE INFECTION ON THE 21-60 AND THE 61-100 YEAR AGE CLASSES

TABLE 16 — DATA SHOWING THE EFFECTS OF MISTLETOE ON THE PHOTOSYNTHETIC ACTIVITY OF WESTERN YELLOW PINE.

Tree No.	Age	Diameter breast high O. B.	Total height	Total volume	Crown Width	Crown Length	Degree of infection	Crown class	Length of leaf tufts: Lower portion of crown Min.	Lower portion of crown Max.	Lower portion of crown Aver.	Lower portion of crown No. of tufts	Center of crown Min.	Center of crown Max.	Center of crown Aver.	Center of crown No. of tufts	Upper portion of crown Min.	Upper portion of crown Max.	Upper portion of crown Aver.	Upper portion of crown No. of tufts	Mean for entire crown Min.	Mean for entire crown Max.	Mean for entire crown Average
	Yrs.	Inches	Feet	Cu.ft.	Feet	Feet			Ins.	Ins.	Ins.		Ins.	Ins.	Ins.		Ins.	Ins.	Ins.		Ins.	Ins.	Ins.
103	80	7.5	20.0	2.50	10.0	15.5	xxx	X	0.5	7.0	3.2	81	1.0	8.0	3.8	329	1.0	12.0	5.7	234	0.8	9.0	4.2
104	79	14.5	42.0	19.00	17.0	32.0	0	X	1.0	11.3	5.3	2161	2.0	13.0	5.4	2390	2.0	18.0	8.0	1151	1.6	14.1	6.2
105	83	8.1	26.0	3.55	8.5	18.5	XXX	C	0.3	11.0	3.7	242	0.5	12.0	4.0	183	0.6	13.0	5.0	176	0.4	12.0	4.2
106	83	15.2	49.0	22.50	22.0	42.0	0	C	1.0	11.0	4.0	1522	1.5	17.0	6.7	1228	2.0	26.0	7.7	445	1.5	18.0	6.1
107	37	27.1	21.0	12.40	12.0	18.0	0	D	1.5	12.5	6.8	379	2.5	18.0	8.8	321	2.5	28.0	10.0	313	2.1	19.5	8.5

Tree No.	Total number of tufts in entire crown	Length of leaves: Lower portion of crown Mean Min.	Lower portion of crown Mean Max.	Lower portion of crown Mean Aver.	Lower portion of crown No. of leaves	Center of crown Mean Min.	Center of crown Mean Max.	Center of crown Mean Aver.	Center of crown No. of leaves	Upper portion of crown Mean Min.	Upper portion of crown Mean Max.	Upper portion of crown Mean Aver.	Upper portion of crown No. of leaves	Mean for entire crown Mean Min.	Mean for entire crown Mean Max.	Mean for entire crown Mean Aver.
		Ins.	Ins.	Ins.		Ins.	Ins.	Ins.		Ins.	Ins.	Ins.		Ins.	Ins.	Ins.
103	644	1.6	3.3	2.6	13,122	1.7	3.5	2.6	62,181	1.8	4.5	3.2	84,240	1.7	3.7	2.8
104	5702	2.5	4.9	3.5	518,640	2.8	5.1	3.7	803,040	2.8	5.1	4.1	470,759	2.7	5.0	3.7
105	601	2.0	4.1	3.2	109,142	2.3	4.2	3.1	67,161	3.1	5.0	4.3	85,712	2.4	4.4	3.5
106	3195	4.1	5.8	4.9	365,280	4.4	6.7	5.7	289,808	4.8	6.8	5.9	182,605	4.4	6.4	5.5
107	1213	3.3	5.2	4.5	94,371	4.1	5.7	5.1	172,972	5.2	6.4	5.9	152,431	4.3	5.7	5.1

Tree No.	Total number of leaves in entire crown	Leaf surface: Lower portion of crown	Center portion of crown	Upper portion of crown	Entire crown	Ratio of leaf surfaces	Ratio of volumes
		sq. ins.	sq. ins.	sq. ins.	sq. ins.		
103	159,543	4,094.1	19,400.4	32,348.2	55,842.7	1.0	1.0
104	1,792,439	217,828.8	356,549.8	231,613.4	805,992.0	14.4	7.6
105	262,015	40,910.5	24,983.9	44,427.4	120,321.8	2.1	1.4
106	837,093	218,438.4	198,228.7	128,939.5	544,606.6	9.9	9.0
107	419.774	50,960.3	105,868.9	107,921.4	264,750.3	4.7	.96